KEYNOTE ADDRESS 1: THE COAL-POWER SUPPLY CHAIN: REGIONAL DEVELOPMENT AND INVESTMENT ISSUES

Dr Guillermo Balce
Executive Director
ASEAN Centre for Energy
Jakarta, Indonesia

DR. GUILLERMO R. BALCE

Executive Director
ASEAN Centre for Energy (ACE)

Dr. Guillermo R. Balce is the first Executive Director of the ASEAN Centre for Energy (ACE), with a term of five years beginning at ACE's establishment date on 1 January 1999.

Formerly, he was Assistant Secretary for Operation of the Department of Energy of the Philippines. He was headquartered in Bangkok in 1989-1992 as Director of the Technical Secretariat of the Committee for Coordination of Prospecting for Mineral Resources in Asia Offshore Areas (CCOP), an intergovernmental organization established from an international cooperation programme under the UN Economic and Social Commission for Asia and the Pacific (ESCAP). From 1987 to 1989, he was Director of Mines and Geosciences of the Philippine Department of Environment and Natural Resources (DENR).

Before reaching the top management level of governmental and intergovernmental institutions on mining and energy, Dr. Balce had 26 years of career service in the Philippine Government. He started in 1961 as Junior Geologist involved in hydroelectric dam foundation surveys at the National Power Corporation. In 1962, he transferred to the Bureau of Mines and Geosciences where he rose through the ranks from Geologist to Chief Geologist. At the start of the new Philippine government in 1986, he was appointed as Assistant Director of the reorganized Mines and Geosciences Bureau at the DENR. Besides his career as geologist, Dr. Balce also served in various capacities in government such as: Director of Mines Research, Philippine Council for Agriculture and Resources Research and Development (PCARRD); Examiner, Board of Geology Professional Regulations Commission; Chairman Division XII (Earth Sciences) of the National Research Council of the Philippines; and Professorial Lecture at the National Institute of Geological Sciences of the University of the Philippines. As Philippine Focal Point for the International Decade of Ocean Exploration (IDOE) Programme from 1972 to 1985, Dr. Balce was instrumental in raising Philippine capacities in tectonic analysis and sea-bed exploration. With the assistance of the Japan International Cooperation Agency (JICA), he was also instrumental in setting up, in 1983, a modern petrological laboratory (PETROLAB) at the Mines and Geoscience Bureau.

During 1992-1994, Dr. Balce was engaged in private practice. He was Senior Technical Consultant of Alcorn Petroleum and Minerals Corporation and President of the Asia Geodyne Corporation. Most of his projects during this period were on environmental impact assessment, hydroelectric resources evaluation and dam foundation surveys. He was also Associate Editor of the Journal of Southeast Asian Earth Sciences published by Elsevier.

The academic preparation of Dr. Balce started at the University of the Philippines, where he completed his Bachelor of Science in Geology in 1961. He completed a Master of Science in Economic Geology in 1969 and a Doctor of Science in Economic Geology in 1978, both at the Tokoku University during 3 –year stints as Japanese Ministry of Education Scholar seconded by the Philippine Bureau of Mines and Geosciences. He completed a Management Development Programme course at the Asian Institute of Management in 1979. In 1987, he entered the Master of National Security Administration course at the National Defense College of the Philippines (NDCP) which he was unable to complete as he was unexpectedly called back to the Mines and Geoscience Bureau to assume the responsibility of Director of Mines and Geosciences.

THE COAL-POWER SUPPLY CHAIN:
Regional Development and Investment Issues*

By
Guillermo R. Balce
ASEAN Centre for Energy
Jakarta Indonesia

INTRODUCTION

Coal occupies 23 percent of the ASEAN fuel mix for energy. Assuming a business–as-usual scenario or "base case" scenario, we at the ASEAN Centre for Energy, have projected a phenomenal growth of coal during the next 20 years. By 2010, the share of coal will rise to 42 percent and by 2020, it will rise further to 52.7 percent. **(Fig. 1).**

This statistically derived projection is corroborated by the actual and planned coal-fired power plant capacities. In 1998, the actually installed coal-fired power plant capacity in the region was 11,072 MW. **(Fig. 2).**

Within 2001 – 2006, an additional 8,631 MW are expected. During the succeeding 5–year period for 2006 – 2011, again some 11,094 MW are planned for installation. **(Fig. 3).**

With this picture of a very robust growth in coal utilization in the ASEAN, it is but necessary for us in this industry to look at the coal power supply chain and the regional issues that relate to the development of that supply chain.

THE COAL SUPPLY CHAIN

The coal supply chain in the ASEAN Countries can be classified into two types. One chain supplies coal from a mine, direct to a power plant, via different types of conveyances such as trucks, conveyors, railways and waterways. This is typical for power plants that are linked inland with a coal mine such as those in Indonesia, Vietnam and partly in Thailand. **(Fig. 4).**

Another type of chain supplies coal from a mine through various types of transport conveyances and through intermediate stockpiling and bunkering projects. This is typical of the power plants in the Philippines where coal is transported mainly through inter-island shipping.

* *For presentation at the APEC Coal Trade and Investment Liberalization and Facilitation Workshop. Hanoi, Vietnam; 7-8 November 2000.*

COAL TRANSPORT SITUATION

The most important component of the coal supply chain is transport. In Indonesia, transport is provided by a few kilometers to a thousand kilometers of roadways, conveyors, railways and waterways. Because, Indonesia is a major coal exporting economy, coal ports are well developed. There are 17 coal loading terminals and coal ports that can handle 5,000 to 200,000 DWT of coal. **(Fig. 5).**

In Malaysia, coal transport is through roadways, railways and waterways. Imports from Australia and Indonesia are through waterways in vessels ranging from 3,000 DWT to 60,000 DWT panamax type. There are receiving ports dedicated to supply coal to power stations and cement plants. **(Fig. 6).**

In the Philippines, coal is transported through roadways and waterways only. Within distances of a few kilometers to 180 kilometers, trucks are used from mine sites to power plants or outloading ports. Vessels of various types from tugboats and barges to panamax vessels are used to transport 5,000 to 60,000 DWT of coal per shipment. There are 18 strategically located loading ports. **(Fig. 7).**

Thailand also uses roadways and waterways for coal transport. Barges and bulk carriers up to 120,000 DWT capacities are used in the waterways. There are three major terminals that can accommodate panamax shipments between 50,000 and 120,000 DWT. These terminals accept mainly the coal imports of the economy. **(Fig. 8).**

Vietnam, like Indonesia, is a coal exporting economy. Its local coal supplies are all from domestic sources. The transportation system is through roadways, railways and waterways. Many ports are located in river and sea docking areas. The other ASEAN countries such as Brunei Darussalam, Cambodia, Laos and Singapore do not as yet use coal for power generation.

COAL EXPORT FLOW

Indonesia and Vietnam are the two ASEAN countries that export coal. In 1998, Indonesia exported 55.32 million metric tons while Vietnam exported 3.0 million metric tons. The bulk of these exports was absorbed by the ASEAN neighbors. But, substantial amounts went to Japan and Taiwan. The transport infrastructures are apparently well developed in so far as the present day coal exports are concerned. The receiving facilities in the importing ASEAN countries also appear to meet the current requirements. **(Fig. 9).**

REGIONAL DEVELOPMENT ISSUES

The rapid growth in coal demand for power generation could easily be perceived to mean that it is imperative to pursue a corresponding advancement in the coal-power supply chain. This is strongly supported by the fact that the ASEAN region is relatively well endowed with indigenous coal resources.

Although Indonesia is favored with about 79 percent of the 46.9 billion tons of ASEAN coal, six other member countries have a share of the endowment. Moreover, as we have projected in our earlier paper (Balce, Zamora and De Bakker, 2000) the current ASEAN coal reserves could last for about 400 years. Therefore, there appears to be no reason why the ASEAN countries should not pursue a robust development of its coal resources and maximize their utilization for power generation. **(Fig. 10).**

This rosy future for coal is, however, constrained by several issues. Most important of the issues that are of regional significance are: 1). the regional energy infrastructure projects; 2). power restructuring; 3). environmental concerns; 4). technological and economic issues; and 5). financing. **(Fig. 11).**

REGIONAL ENERGY INFRASTRUCTURE PROJECTS

The ASEAN pursues two regional energy infrastructure projects aimed at integrating the energy systems of the Southeast Asian region. These are the ASEAN Power Grid and the Trans-ASEAN Gas Pipeline.

The ASEAN Power Grid (APG) project strongly favors coal as fuel for power generation since it will enhance the utilization of coal deposits even in remote areas of the region. The integrated grid would encourage the setting-up of power plants near coal deposits and even mine-mouth coal-fired power plants because the grid would physically provide access to electricity demand centers at long distances and across borders. The savings in the transportation cost of coal would enhance its competitiveness against other fuels such as natural gas and large hydros. With the reduction of coal supply infrastructure requirements the economies of scale advantage of large plants would become less relevant, thus paving the way for more small-scale coal-fired power plants. This will enable greater utilization of indigenous coal deposits; even the small ones that are widely distributed in Southeast Asia. It will also enable the application of clean coal technologies which currently are technically viable only at small scales. **(Fig. 12).**

The other major regional energy infrastructure project, the Trans-ASEAN Gas Pipeline (TAGP), would naturally work against coal. However, the need for continuous and stable electricity supply, especially at the base load level, would project the share of coal in the fuel mix of those countries already utilizing coal as a major power source. For some countries, where coal has a minor role in the fuel mix, an expansion of that role would be needed to ensure security of electricity supply through fuel diversification. **(Fig. 13).**

Looking at the issue in another vein, one could envision a shifting to natural gas of coal-fired power plants once the gas pipeline infrastructure is available. This is a realistic possibility. However, the benefits offered by a well-developed natural gas infrastructure can be equaled or even surpassed by a well-developed power grid. Thus, as long as the ASEAN Power Grid project progresses even as the TAGP also progresses, shift from coal to natural gas would not drastically reduce the share of coal as additional coal-fired power plants would continue to be installed. However, because of the facility provided by an integrated power grid to smaller and mine-month power plants, there will be a tendency to shift from imported coal to indigenous coal. Here, we can see a need for change in the coal-power supply chain.

POWER RESTRUCTURING

Practically all of the ASEAN member countries adhere to the concept of a market-oriented competitive system in the power industry. From a monopolistic structure, the trend is to shift towards the structure where the customer would have the choice. The shift is however at its initial stages in the ASEAN. At present, Singapore is the most advanced having unbundled the power industry into functional business concerns and created a competitive power pool where several nearly privately-owned and government-owned power generators are now competing for the supply market. Malaysia, Philippines and Thailand have internally unbundled their national power utilities in preparation for privatization of the generation and distribution components of their electricity business. All the other countries have adopted a policy of encouraging private participation especially in the generation function. Thus, independent power procedures (IPP) have been in operation in most countries since the past five years. It is, however, unfortunate that the entry of many of these IPPs coincided with the recent financial crisis that their viability and suitability have been questioned. On the other hand, these IPPs remain to be the most viable source of financing and management skills in power generation. It is, therefore, likely that IPPs would remain and even expand as the power demand growth goes back to pre-crisis levels. **(Fig. 14).**

In terms of the coal-power supply chain, power restructuring could easily be viewed as a positive influence. Participation of the private sector in power generation could favor coal over other fuels as coal-fired power plants offer the least-cost in preparation, siting and installation. Especially in countries where electricity demand is fast-growing, the fact that coal-fired power plants require the least-time for installation, they should be the preferred fuel of the IPPs. As had happened in the Philippines, the power crisis in the 1990's resulted in the installation of 1,500 MW coal-fired power plants by IPPs from 1992 to 1998. One important aspect of this Philippine experience is the drastic expansion of coal imports and the establishment of large-scale coal terminals mostly dedicated to the power plants.

ENVIRONMENTAL CONCERNS

On the macro-level, coal demand is substantially reduced in response to environmental concerns. This is clearly demonstrated by comparing a business-as-usual or baseline scenario with environment friendly scenario in coal demand forecasts. One such forecast is the APERC (APEC Energy Research Center) forecast. There it is shown that employing environment-friendly systems in power generation reduces the coal demand substantially: 5 million tons in 2000, 13 million tons in 2000 and 27 million tons in 2010. This scenario is expected to lower the emissions of power plant substantially. **(Fig. 15).**

It is assumed that coal-fired power plants would be made to comply with environmental emission standards of the ASEAN countries. Indonesia, Malaysia, Philippines, Thailand and Vietnam have standards for particulates, SO_x, and NO_x. **(Fig. 16).**

The reduction in demand of coal due to the need to reduce environmental emissions does not, however, redound to a curtailment of coal demand growth. It only reduces that growth. But we can expect more coal-fired power plants to be established in the ASEAN countries during the next twenty years.

In the terms of the coal-power supply chain, environmental issues should therefore be considered seriously in extending measures to expand the chain. This could mean that infrastructure in the supply chain must adopt to only the concrete plans for coal-fired power development. Regional coal-power supply infrastructure may therefore be a possibility only if the environmental constraints of coal use could be overcome or at least reduced substantially.

TECHNOLOGICAL AND ECONOMIC ISSUES

The technological and economic issues affecting coal-power supply relate mainly to the measure by which environmental emissions are reduced. Such measures are employed in three stages: a) pre-combustion; b) combustion; and c) post-combustion.

Among the pre-combustion technologies, the most efficient are chemical and biological cleaning, gasification, and liquefaction. The problem is the additional cost incurred in employing these technologies. However, this cost could be reduced as R&D continues. Here, we take note of the progress in coal liquefaction research in Indonesia with the assistance of the New Energy Development Organization of Japan.

In the area of combustion technologies, those available five years ago are still the same promising technologies at present. The IGCC technology is the most promising but only few commercial units have been established and application is limited to large-size gas turbines. There is certainly a great need for continued research to lower the cost of these technology, upgrade efficiency, and apply at both small and large scales. For Southeast Asia, small scale applications would encourage utilization of these technologies. **(Fig. 18a, 18b).**

On post-combustion technologies, the most extensively used for emission reduction is Flue Gas Disulfurization (FGD). The other technologies have lower emission reduction capabilities, but their costs are also much lower. Application of these technologies is however dictated by the type of coal and pre-combustion, and, combustion technologies used. **(Fig. 19).**

In terms of economics, utilizing clean coal technologies does not really make coal non-competitive against other fuel options. Using 1999 prices when petroleum crude oil was in its lowest during the past ten years, coal-fired generation still appeared to be lower than its closest rival, gas-fired combined cycle. In terms of fuel price the gas price in 1999 was lower than the market price of coal. But currently, this situation has reversed with the recent upgrading of natural gas prices. **(Fig. 20).**

We can therefore conclude at this point that clean coal technologies do not necessarily remove the competitive advantage of coal over other fuels. They could even increase the demand for coal as environmental emissions are reduced. It is likely that the reduction in the demand growth of coal that we project due to an environment-friendly scenario could be abated through more extensive use of these technologies. The prospect of utilizing more indigenous coal resources for most of the ASEAN countries would be the strongest incentive to support a strong coal demand growth.

FINANCING ISSUES

Another major issue that affects the coal-power supply chain is financing. Since we have seen that the supply chain depend largely on the actual demand for coal-fired power plants, we shall suffice to consider primarily the investment requirement of planned coal-fired power plants. We see that requirement to increase progressively from about 7.0 B USD in 1996 – 2001, to 11.5 B USD in 2001 – 2006 and 13.2 B USD in 2006 – 2011. The total investment requirement is 31.73 from 1996-2011. These figures are based on actual or assumed construction costs for the ASEAN countries with plans to put up coal-fired power plants in the next ten years. The large size of this financing requirement necessitates the involvement of the private sector foreign investment sources. Consequently, the current push for the restructuring of the power sector in most of the ASEAN countries would enhance the entry to the ASEAN region of such investments. **(Fig. 21).**

CONCLUSION

In closing, we find that considering a business-as-usual scenario, coal could occupy as large a share of the ASEAN energy mix; up to 52.7% in 2020. However, the demand for coal in the power industry is regulated by several issues such as:

1. the energy infrastructure projects;
2. restructuring;
3. environmental issues;
4. technological and economic issues; and
5. financing.

The ASEAN Power Grid Project favors an increase in coal demand but the Trans-ASEAN gas pipeline works on a counter direction. Restructuring of the power sector in the ASEAN countries would expand the role of the private sector, especially IPPs in power generation. This will favor expansion of coal demand. But, environmental issues would depress the demand growth although not enough for technologies are available without removing the competitive advantage of coal over other fuels. Financing the 31.73 B USD requirement for just the planned coal-fired power plants during the next ten years would be a big burden to governments. But participation of the private sector in restructured power industries of the ASEAN countries would provide the solution.

The demand for coal in the power industry is a primary factor that governs the coal-power supply chain. Any plan for the development of this supply chain must therefore be linked to concrete plans for coal-fired power generation. On this ground, regional development of coal infrastructures may be a possibility only if such infrastructures would tend to remove or reduce the environmental constraints of coal use.

The Coal-Power Supply Chain:

Regional Development & Investment Issues

By

Dr. Guillermo R. Balce,

Executive Director

ASEAN Centre for Energy, Jakarta

Figure 1

COAL DEMAND IN UPDATED (POST-CRISIS) BASE CASE SCENARIO OF ACE TO 2010 ... 2020

FUEL TYPE	2000		2005		2010		2015		2020	
	MTOE	%	MTOE	%	MTOE	%	MTOE	%	MTOE	%
NATURAL GAS	23	37.7	26	32.9	31	27.7	39	24.8	51	23.0
COAL	14	23.0	27	34.2	47	42.0	77	49.0	117	52.7
OIL PRODUCT	14	23.0	12	15.2	15	13.4	17	10.8	20	9.0
HYDRO	7	11.5	10	12.7	13	11.6	16	10.2	21	9.5
GEOTHERMAL	2	3.4	4	5.1	6	5.4	8	5.1	13	5.9
TOTAL	**59**	**100**	**79**	**100**	**112**	**100**	**157**	**100**	**222**	**100**

Figure 2

COAL-FIRED POWER PLANTS INSTALLED CAPACITY

(1998, in Megawatts)

Country	Installed Capacity
Brunei	-
Cambodia	-
Indonesia	5,010
Lao P.D.R.	-
Malaysia	600
Myanmar	-
Philippines	1,900
Singapore	-
Thailand	2,917
Vietnam	645
Total	11,072

Figure 3

COAL-FIRED POWER DEVELOPMENT PLANS OF ASEAN COUNTRIES TO 2010

(In Megawatts)

COUNTRY	1996-2001	2001-2006	2006-2011	TOTAL
INDONESIA	805	130	-	935
LAO PDR	0	0	744	744
MALAYSIA	1,000	2,100	-	3,100
PHILIPPINES	2,850	1,800	600	5,250
THAILAND		3,441	9,450	12,891
VIETNAM	600	1,160	300	2,060
TOTAL	5,255	8,631	11,094	24,980

Figure 4

TYPICAL COAL SUPPLY CHAIN IN ASEAN COUNTRIES

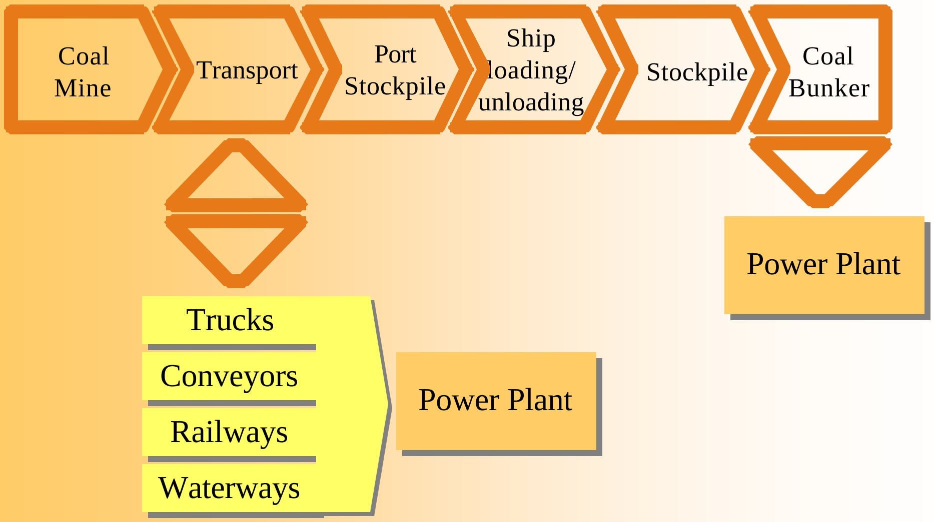


Figure 5

COAL TRANSPORTATION SYSTEM

Country	Transport System				Coal Ports
	Roadways	**Conveyors**	**Railways**	**Waterways**	
Indonesia	• Off-highway haul roads were constructed with 35-170 ton trucks capacity	• PTBA transports coal 12 km to a coal preparation plant • PT KPC transport coal 14 km to a clean stockpile at the port	• In South Sumatra, the railroad system has a capacity of 7 MTPA and to increase to 12 MTPA in 2000 • In Western Sumatra, existing railway extends approx. 155 km from mine sites to the port of Teluk Bayur, Padang	• Vessel types: - 9,200 DWT self-unloading ship - 5,000–8,000 DWT converted log carriers - 5,000–10,000 DWT flat-deck barges - 30,000–60,000 DWT vessels - 150,000–200,000 DWT vessels • The largest barge haul is 5,000 DWT from Berau to Paiton power plant, about 700 miles at ± US$7.8/ton	• 17 coal loading terminals: 3 capesize, 1 panamax, & 3 handy size terminals • Major coal ports: - Kertapati (5,000-10,000 DWT) - Teluk Bayur - Terahan (export point to Malaysia, Philippines, Japan & Taiwan) - Pulau Baai, Bengkulu (50,000 DWT) - Cirebon - Tanjung Bara - North P. Laut - Balik Papan

Figure 6

COAL TRANSPORTATION SYSTEM

Country	Transport System				Coal Ports
	Roadways	Conveyors	Railways	Waterways	
Malaysia	• Along the West coast between Port Kelang on the south and Pelang area of the north • Truck payload capacity: 14 tons • Hauling cost:50 km-US$.05/ton-km>50 km - US$.04/km -ton • Haul range: 60 to 100 km		• Railway has a meter gauge & maximum axle load of 14 tons • Maximum net payload of rail cars is 38 tons • Rail system stretched from Port Kelang to all cement plants (about 50-70 km length)	• Vessel sizes: - 5,000-3,000 DWT geared ships from Australia - 5,000-12,000 DWT geared ships from Ombilin, Indonesia - 3,000-5,000 DWT barges from Kertapati (Palembang, Indonesia) • 3 panamax vessels (up to 60,000 DWT) to Port Kelang power station	• 4 receiving ports, namely: Port Kelang, Lumut Coal Terminal, CIMA cement dock and Kedah cement dock

Figure 7

COAL TRANSPORTATION SYSTEM

Country	Transport System				Coal Ports
	Roadways	Conveyors	Railways	Waterways	
Philippines	• Trucks are used from mine sites to outloading ports • Trucks payload capacity: 12-30 tons • Trucks are covered with tarpanlin sheets to avoid pollution • Distance varies between 1 km to 179 km			• Vessel type: - Tug and 5000 DWT barge - Tug and 10,000 DWT barge - 5,000 DWT Gear-less coal carrier - 10,000 DWT standard bulk carrier - 9,200 DWT self-unloading ship • Imported coal: 60,000 DWT vessel • Distance varies between 50 to 5,000 nautical miles	• 18 strategically located loading ports • Terminals have 5,000 DWT capacity, a vessel unloader, 450 tons per hour receiving conveyor system, truck – loading bin and truck weighbridge • Stockpile capacity of 20,100 tons • Modern dust suppression and sprinkler and pollution control system

COAL TRANSPORTATION SYSTEM

Figure 8

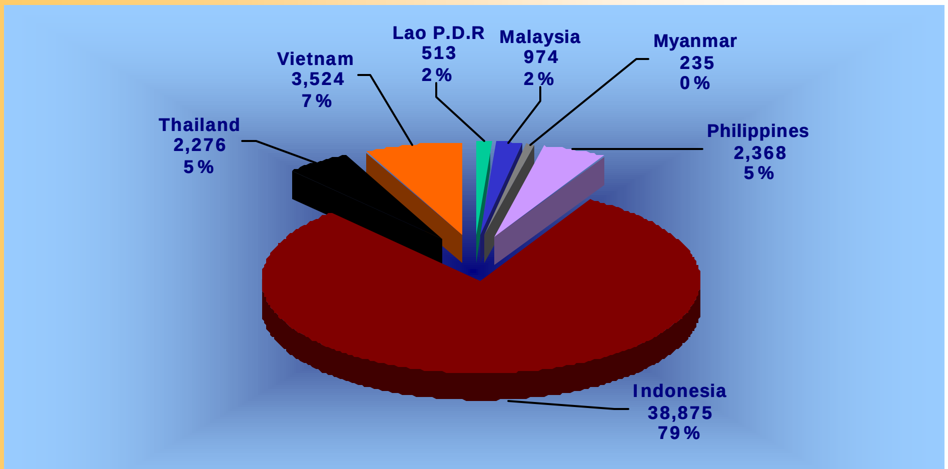
Country	Transport System				Coal Ports
	Roadways	**Conve -yors**	**Railways**	**Waterways**	
Thailand	• Use trucks to transport coal at distances between 100 km to 850 km.			• Barges • Bulk carriers of 50,000, 60,000 and 120,000 DWT capacity	• Major coal terminals: – Bang-Pa–In transfer terminal – Jalaprathan cement, cha Am terminal – Ko Sichang–up to 50,000 DWT – Ao Phai–up to 120,000 DWT – Kantan – – Krabi–up to 60,000 DWT
Vietnam	• Trucks payload capacity: 8 - 45 tons		• Range of coal transport by rail system is 5-17 km from mine site to coal preparation plants • Total length of rail system is ± 75 km • The rail is located along the coastal line & cities causing dust and noise pollution	• Barges • Bulk carriers of 15,000 and 50,000 DWT capacity	• Many ports are located in river and sea docking areas • Major ports are: Cua Ong, Hon Gai, and Dien Cong, South Nam Cau Trang, and Ben Bang

Figure 9

COAL EXPORT FLOW FROM INDONESIA AND VIETNAM

Figure 10

ASEAN Coal Resources by Country, 1999



TOTAL : 46, 917 Million Tons

Figure 11

Regional Issues

1). The regional energy infrastructure projects;

2). Power restructuring;

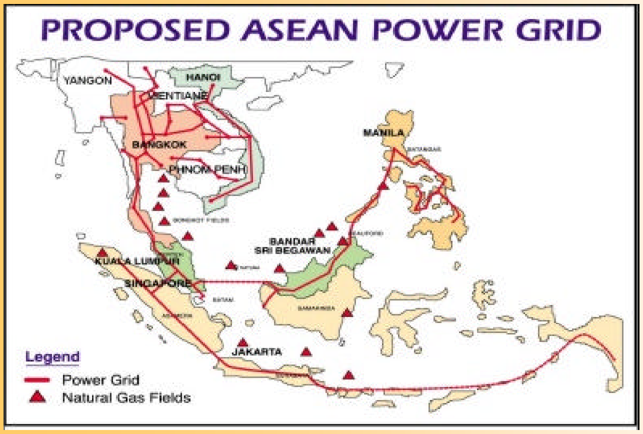
3). Environmental concerns;

4). Technological and economic issues; and

5). Financing.

Figure 12

THE ASEAN POWER GRID



14 Electricity Interconnection Projects

- **Peninsular Malaysia – Singapore**
- **Thailand – Peninsular Malaysia**
- **Sarawak - Peninsular Malaysia**
- **Sumatra - Peninsular Malaysia**
- **Batam – Bintan – Singapore – Johor**
- **Sarawak – West Kalimantan**
- **Philippines – Sabah**
- **Sarawak – Sabah – Brunei**
- **Thailand – Lao PDR**
- **Lao PDR – Cambodia**
- **Thailand – Myanmar**
- **Vietnam Cambodia**
- **Lao PDR – Vietnam**
- **Thailand - Cambodia**

Figure 13

TRANS-ASEAN GAS PIPELINE (TAGP)

- **1996 Masterplan Study by AEEMTRC concluded feasible to 2020**
- **Two conditionalities :**
  - **Development of the giant Natuna gas field in Indonesia**
  - **Discovery of more gas resources, 65% in Indonesia**

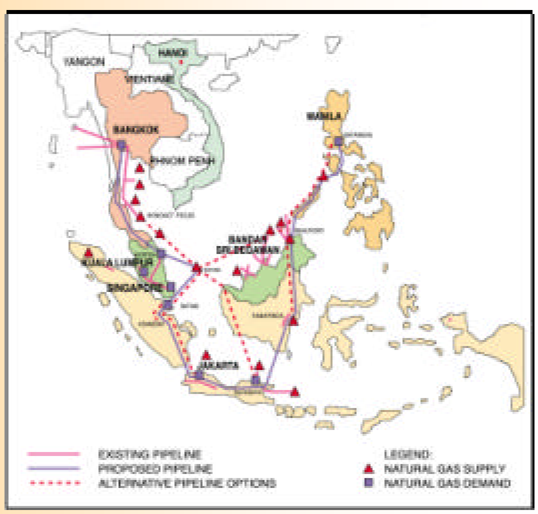


Figure 14

POWER RESTRUCTURING

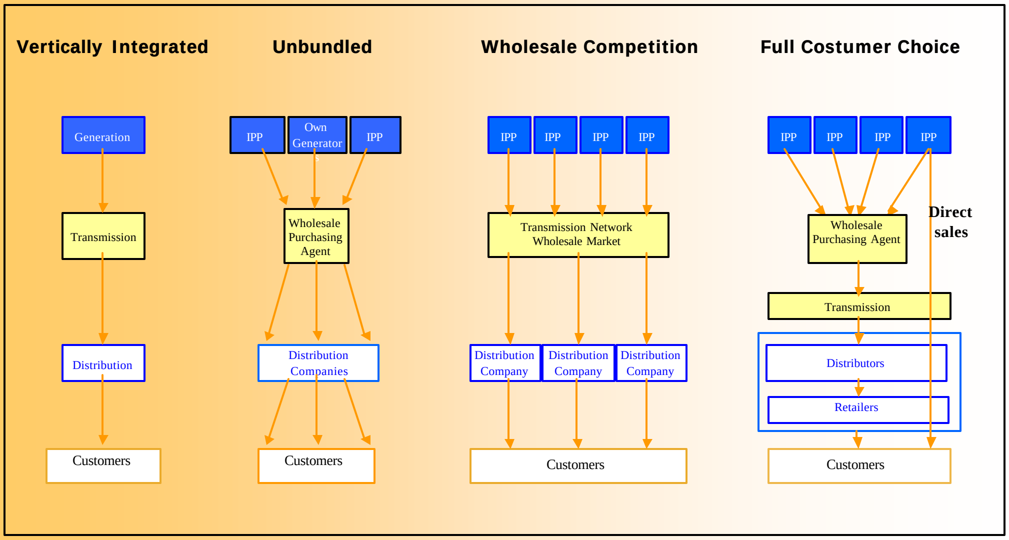


Figure 15

OUTLOOK SYNTHESIS COAL DEMAND
(in Million Tons)

SCENARIO	2000	2005	2010
ACE BASE CASE SCENARIO	(14) 23	(27) 43	(47) 76
APERC BASELINE SCENARIO	(21) 34	(33) 53	(51) 82
APERC ENVIRONMENT FRIENDLY SCENARIO	(18) 29	(25) 40	(34) 55

*( ) MTOE
- CURRENT COAL DEMAND FOR ENERGY : 25 MTOE
- CURRENT COAL PRODUCTION OF ASEAN : 58 MTOE
- RESERVE / PRODUCTION RATIO : 400

Figure 16

ENVIRONMENTAL EMISSION STANDARDS FOR COAL-FIRED POWER PLANTS (in mg/m^3)

Country	Particulates	Sulfur dioxide	Nitrogen dioxide
Indonesia	150	750	850
Malaysia	50	750	650
Philippines	150	700	1,000
Thailand	120	> 500 MW – 850 300 – 500 MW – 1,200 < 300 MW – 670	1 hr – 400 1 day – 100
Vietnam	Existing Sources: 600 New Sources: 500	Existing Sources: 1,500 New Sources: 500	Existing Sources: 2,500 New Sources: 1,000

Figure 17

TECHNICAL AND ECONOMIC STATUS OF CLEAN COAL PRE-COMBUSTION AND CONVERSION TECHNOLOGIES

Technology	Status	Conversion Efficiency %	Capital Cost (US$/kW)	Emissions Reduction (%)	
				SOx	NOx
PHYSICAL CLEANING	Commercial/ Demonstrated	90	1-3	30	n.a
CHEM/BIO CLEANING	R&D	85-90	5-10	90-95	n.a
LOW RANK UPGRADING	R&D	80	1.5	30-95	n.a
COAL/WATER MIXTURES	Demonstrated	n.a.	n.a.	50-75	n.a
GASIFICATION	Commercial/ Demonstrated	75-80	n.a.	90-99	n.a
INDIRECT LIQUEFICATION	R&D	60	n.a.	95	70
DIRECT LIQUEFICATION	R&D	55-60	n.a.	99	97

Note: Conversion efficiencies measure the ratio between heating value of the fuel in process output and input

Source: IEA (1997e)

Figure 18a

TECHNICAL AND ECONOMIC STATUS OF CLEAN COAL COMBUSTION TECHNOLOGIES

PARAMETER	SUBCRITICAL PF	SUPERCRITICAL PF	AFBF	PFBC	IGCC
MATURITY OF TECHNOLOGY	Completely proven	Substatially proven	Proven at small scale (<200 mw) only	Only five commercial units built, limited experience	Only one commercial unit
RANGE OF UNIT SIZE AVAILABLE	All commercial size available	All commercial size available	Small units only at present	Currently limited to two sizes	Currently limited to large gas turbine units
FUEL FLEXIBELITY	Burns a wide range of coals, but less good than FBC extremes of moisture/ash	Burns a wide range of coals, but less good than FBC extremes of moisture/ash	Will burn practically anything that can be burned	Should burn same range as AFBC but not proven	Should use wide range of coals, but not proven
THERMAL EFFICIENCY	36-38% Limited by steam conditions	40-46% High, further increase depends on materials development	34%-40% Relatively low, but supercritical steam conditions will raise	42%-45% Inherently less good than IGCC Topping/ 2nd generation will raise	43%-48% High, further increases as gas turbines improve

Figure 18b

PARAMETER	SUBCRITICAL PF	SUPERCRITICAL PF	AFBF	PFBC	IGCC
OPERATIONAL FLEXIBLELITY	Performance limited at low load	Performance limited at low load	Wide load range and response	Potentially similar to pf but needs proof	Limited experience, needs demonstration *
ENVIRONMENTAL PERFORMANCE	Low efficiency and FGD solids a problem	Better than subcritical because of higher efficiency	Low efficiency and large volume of solids	Good, but solids residues a potential problem	Excellent, inert slag, sulfur recovered in elemental form
AVAILABILITY	Proven to be excellent	Proven to be good	Limited experience at utility scale	Limited experienced	Limited experience, results modest so far
BUILD TIME	On-site erection required	On-site erection required	On-site erection required, but no FGD required	Long so far, but substantial opportunity for modularisation	Long so far, but opportnity for shop fabrication of major items
CURRENT SPECIFIC CAPITAL COST	**US$900-1300/kW Cheapest**	**US$950-1600/kW Medium**	**US$1000-1600/kW Potentially cheaper than PF+FGD**	**US$1100-1500/kW Expensive**	**US$1200-1600/kW Most expensive**

Note: Thermal efficiency is the net efficiency based on the lower heating value of the fuel
Source: IEA (1996c); IEA (1997e)

Figure 19

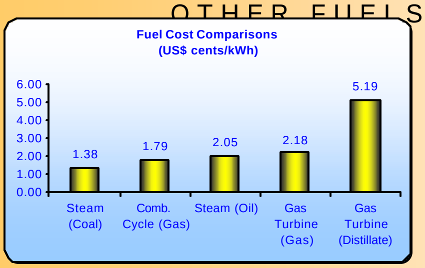
TECHNICAL AND ECONOMIC STATUS OF POST-COMBUSTION TECHNOLOGIES

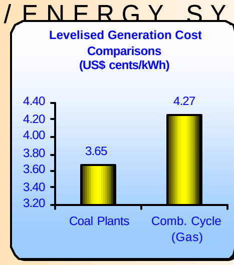
TECHNOLOGY	STATUS	CONVERSION EFFICIENCY %	CAPITAL COST (US$/kW)	EMISSIONS REDUCTION (%)	
				SOx	NOx
ADVANCE FLUE GAS DESULFURISATION (FGD)	Commercial/ Demonstrated	37-39	200-350	90-97	
SORBENT INJECTION	Commercial/ Demonstrated	37-39	88-100	55-75	
SPRAY DRYING	Commercial/ Demonstrated	37-39	120-380	70-90	
COMBINED SOx/NOx	Demonstrated/ R&D	37-39	280-360	70-95	70-90
SCR	Commercial/ Demonstrated	n.a	50-80		>80
REBURNING	Commercial	38-40	15-50	0-2	60
LOW NOx BURNER	Commercial/ Demonstrated	38-40	10-30		45-60
POST-COMBUSTION NOx	Commercial/ Demonstrated	37-38	100-130		40-90

Note: Net plant thermal-electric conversion efficiencies based upon the lower heating value of the fuel and subcritical steam cycle. Capital costs add to power plant investment
Source: IEA (1997e); APEC (1997a)

Figure 20

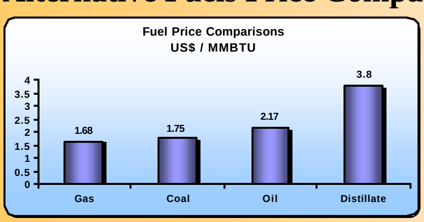
COMPARATIVE COST OF ENERGY GENERATION WITH CLEAN COAL TECHNOLOGIES VS. OTHER FUELS/ENERGY SYSTEMS





Generation cost of coal plant is lower than gas-fired combined cycle plants.

Alternative Fuels Price Comparisons



The current fixed gas price is slightly lower than the market coal price.

Figure 21

INVESTMENT REQUIREMENT OF PLANNED COAL-FIRED POWER PLANTS OF ASEAN COUNTRIES TO 2010

(in Million US Dollars)

COUNTRY	1996-2001	2001-2006	2006-2011	TOTAL
INDONESIA	821.1	132.6	0	**953.7**
LAO PDR	0	0	967.2	**967.2**
MALAYSIA	1,664.0	3,494.4	0	**5,158.4**
PHILIPPINES	3,705.0	2,340.0	780.0	**6,825.0**
THAILAND	0	4,043.2	11,103.8	**15,146.9**
VIETNAM	780.0	1,508.0	390.0	**2,678.0**
TOTAL	**6,970.1**	**11,518.2**	**13,241.0**	**31,729.2**

Country	Net Capacity (MW)	Base Construction Cost
Indonesia	600	US$ 1020 / kW
Lao PDR*	Average	US$ 1300 / kW
Malaysia	200	US$ 1664 / kW
Philippines	Average	US$ 1300 / kW
Thailand	Average	US$ 1175 / kW
Vietnam*	Average	US$ 1300 / kW

* Assumption